

Electrical Performance and Effect of Frequency Electromagnetic Waves on Subterranean Termites *Coptotermes curvignathus* Holmgren

Seno D. Panjaitan¹, Farah Diba², Ferry Hadary¹, Tsuyoshi Yoshimura³

¹Department of Electrical Engineering, Faculty of Engineering, Tanjungpura University, Pontianak, Indonesia; ²Department of Forestry, Faculty of Forestry, Tanjungpura University, Pontianak, Indonesia; ³Research Institute for Sustainable Humanosphere, Kyoto University, Kyoto, Japan.
Email: senopanjaitan@gmail.com

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ABSTRACT

The research aimed to propose a non-destructive technology to control subterranean termites *Coptotermes curvignathus* Holmgren infestation based on electromagnetic waves. A portable apparatus for this technology has been built and its experiment is presented in this paper. Some electrical parameters were measured and analyzed along with their effects to the termites. The experiment using frequency range between 30 Hz - 600 kHz has been done. The average error of the apparatus by comparing the result with the direct measurement using oscilloscope was also measured. The highest error value appeared at 600 kHz with frequency error 6.05 kHz. The highest error of voltage (*i.e.* 0.186 Volt) appeared at 100 kHz. For safetiness, the highest magnetic field at 300 kHz was 0.1815 μ T and at 500 kHz was 0.00725 μ T which were safe for human. The average value of termites mortality was higher on irradiation time 120 minutes than 60 minutes respectively in all test frequency: 300 kHz, 400 kHz, 500 kHz and 600 kHz. This paper presents an important information of the electromagnetic-based technology for environmental friendly termites control in spite of using the insecticides.

KEYWORDS

Electromagnetic Waves; Frequency; Subterranean Termites; *Coptotermes curvignathus*; Termites Infestation

1. Introduction

Nowadays, termites are known as a group of serious pests in the world. They often cause serious damage to wooden furnitures and buildings. The damage caused by termites has an important economic effect. In Indonesia, the damage costs could reach to 100 - 300 billion rupiahs every year [1]. One of the important groups of urban insect pests in tropical countries is subterranean termites *Coptotermes curvignathus* Holmgren [2]. Termites are insects which are successfully to adapt in various condition of settlements and farms. Their ability to survive in settlements area is also influenced by their life style which is colonized in big numbers [3]. The chemical treatments, including soil treatment, wood impregnation, or fumigation have been widely used over the last few

decades. However, an increased public concern about unfavorable effects would not support the massive use of insecticides any more [4]. Concisely, the use of chemical treatments may bring a destructive effect to the environment.

A new solution to control the termites is urgently needed which is an attractive research issue. The on-site termite treatment with physical methods is one of the most promising alternatives. One of the technologies which are potential to be developed is the use of electromagnetic waves technology. Electromagnetic wave or electromagnetic radiation is a combination of electric and magnetic fields that oscillate and propagate through space and carry energy from one place to another [5]. In the present day, the use of electromagnetic waves has

also been considered in efforts to eliminate termites. Some patents related to the use of electromagnetic technology such as US Patent No. 5,473,836 issued to Liu [6], which disclosed a method for removing insects from hidden place by inducing an electromagnetic field to create physical vibrations. Another US Patent No 5,442,876 issued to Pederson [7] disclosed a method for controlling termites by heating the area where termites were located by means of electromagnetic energy. This technology is odorless, noiseless, environment friendly and easy to apply. However, there is no detail research conducted on the response of about subterranean termites *Coptotermes curvignathus* against electromagnetic waves.

This paper presents the research development on the use of electromagnetic waves to repel or to eliminate the subterranean termite *Coptotermes curvignathus* by means of changing their common behaviour. The main objective of this study is to build and test an apparatus developed to produce variable electromagnetic waves to influence the behavior of termites and to prevent their infestation in buildings.

2. Materials and Method

The research was carried out in Tanjungpura University Pontianak (Indonesia) and Research Institute for Sustainable Humanosphere (RISH) Kyoto University (Japan). The primary circuit built for the apparatus were as follows: voltage control, frequency control, amplifier, microcontroller circuit, rectifier, Liquid Crystal Display (LCD) circuit, and electromagnetic transmitter. The apparatus was covered by an acrylic package. Some materials used for the experiment were termites *Coptotermes curvignathus*, wood dust, sand and distilled water as substrate for termites breeding, Whatman filter paper, distilled water, petridish, and analytic balance. Furthermore, several measurement equipments used were electromagnetic field (EMF) tester (Hioki 3470-10, Japan), function generator and oscilloscope.

The procedure of this research consisted of two main parts: 1) apparatus development, testing and electrical performance analysis and 2) bioassays. The development of a compact termites control apparatus (TCA) (cf. **Figure 1**) involved several functionalities such as power supply, voltage and frequency control, voltage and frequency display, electromagnetic generation. The analysis of electrical parameters performance was dealt with frequency, voltage, waveform and electromagnetic field. The electric power output (P) was measured by power meter and power density was calculated as follow:

$$D \approx \frac{P}{\frac{\lambda}{4} \times \frac{\lambda}{2}} \text{ (mW / cm}^2\text{)}$$

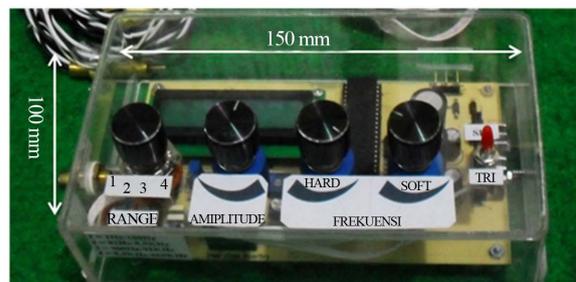
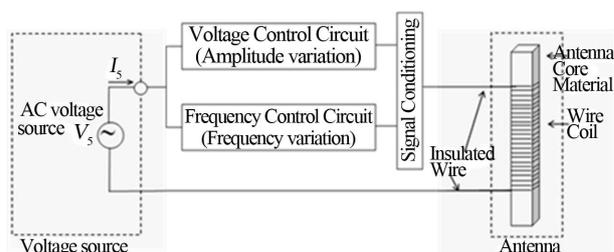


Figure 1. The Developed Termites Control Apparatus.

The design and building the apparatus was done in Control Systems Laboratory, Engineering Faculty, Tanjungpura University, Indonesia. The design was based on some references [8-10]. The proposed concept mainly adopted the previous concept of the authors [11] by developing frequency range, compatibility and electromagnetic field range. In our previous research [11], the optimal frequency to repel the termites was about 300 kHz with a limitation on the electromagnetic field radius (5 - 10 cm), limit of voltage in the higher frequency (about 2 Volt in frequency about 300 kHz) and its incompatibility (frequency and voltage setting had to use the oscilloscope).

The development of it presented in this paper increase the frequency range and compatibility faced at the beginning of the development. The built apparatus provides a frequency range between 0 - 600 kHz, voltage range 0 - 16 Volt, and a compatibility product (frequency and voltage setting could be performed directly at the apparatus). By the providing frequency and voltage set panel in the apparatus, the user will be easily use and set the required frequency and voltage which is determined by the research results. This is one step to the commercial product.

Furthermore, the subterranean termite *C. curvignathus* colony was taken from Arboretum Forestry Faculty, Tanjungpura University and maintained in the Wood Laboratory of Forestry Faculty at 25°C and 75% RH. For testing the TCA, a construction model of a residential building-like test-bed shown in **Figure 2** was built. Scale of the model was 500 mm width, 1000 mm length and 250 mm height. It was built by using transparent acrylic material for the walls and several wood made furniture inside of the house.

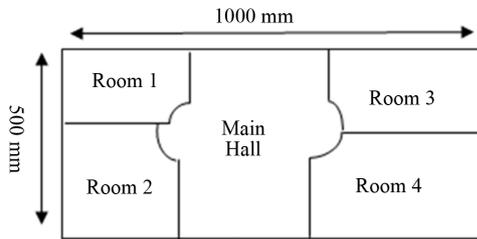


Figure 2. A Residential Building-like Test-bed.

Bioassays with the TCA to termites in the test-bed were performed afterwards. Effect of the electromagnetic fields was analyzed by putting the TCA on the top of the room 4 of residential building test bed. The container which measure 5 mm height and 120 mm diameter then put inside the room 4. Mature workers and soldiers of *C. curvignathus* then put into container which contain filter paper as a food for termites. The numbers of termites used were 100 soldiers and 1000 workers. This number was selected to obtain a nearly equal weight/volume of termites for electromagnetic waves irradiation. The frequencies of TCA used were 300 kHz; 400 kHz; 500 kHz and 600 kHz respectively. Time exposure of TCA to termites was 60 minutes and 120 minutes. Termites behavior during bioassay was observed. After irradiation of electromagnetic waves, termites were removed to petri-dish to evaluate the termites mortality. Petridish with diameter 120 mm contained filter paper (Whatman No 2) which saturated with 0.4 ml distilled water. Termites were kept for 24 hour in a termite culturing room, and then afterwards the mortality of termites was count. Termite mortality was calculated based on Nakai *et al.* [12] as follows:

$$\text{Termites Mortality}(\%) = \frac{N_2}{N_1} \times 100\%$$

N_1 = Number of initial termites

N_2 = Number of death termites after 24 hour exposure

Evaluation of the safetiness of electromagnetic effect for human and non-target organisms was further analyzed by using Electro Magnetic Field (EMF) tester (Hioki 3470-10, Japan). The measurement was performed by putting TCA in several positions regarding the x-y-z axis of the EMF tester according to Thide Bo [13]. The result was compared to home electronic equipments magnetic field listed by Kato [14]. Thus, the safetiness of the TCA was concluded.

3. Results and Discussion

3.1. Electrical Performance

The electrical parameters performance was measured by

classifying into several group of frequency, *i.e.* 30 Hz, 150 Hz, 300 Hz, 1 kHz, 2 kHz, 3 kHz, 10 kHz, 15 kHz, 30 kHz, 40 kHz, and 50 kHz respectively. **Figure 3** shows the electrical parameters regarding set frequencies which are shown on LCD display of apparatus and the maximum voltage that can be set.

The maximum voltage set in the TCA was 20 Volt, while in the higher frequency it tended non-linearly to operate with lower frequency. This is caused by the requirement of current (necessity for more power to operate the TCA) for some frequency groups become higher than the lower frequency groups. To improve the voltage value of the TCA, the amplification could be done along with the power of it.

Furthermore, the average of rising time in accordance with the set frequency depicted in **Figure 4**. This data is used for explain the stability of electromagnetic waves for some period of time by the influence of the used frequency. The results shows how fast the real voltage could reach the set voltage. The lower frequency resulted the higher rising time, although it is not linier as shown in **Figure 4**. This means that TCA electromagnetic in lower frequency the steady-state could reach faster start from 2000 Hz. Therefore we continued the bioassay of termites to know the influence of TCA to control termite start on 3000 Hz.

In order to examine the precision of frequency and voltage that are set at the TCA, their values were compared to direct measurement using standardized oscilloscope. There were small errors in some set frequency. **Table 1** lists the average error in frequency between 30 Hz - 600 kHz. The highest error of frequency was appear at 600 kHz (*i.e.* 6,05 kHz) and of voltage at 100 kHz (*i.e.* 0.186 Volt). Since the selected frequency was purposed not to apply in the communication field, the approximation could be done hence the percentage of the average error is still acceptable.

Figures 5 and **6** show the waveform and electrical parameters for frequency 300 kHz and 500 kHz. There is no harmonic distortion at both frequencies. The waveform and electrical parameters was taken to be compare to the frequency and voltage shown in the LCD circuit of the apparatus.

In the set frequency 300 kHz, there is a small error of frequency, where the real frequency is 301.2 kHz and the error is 1.2 kHz. Since the purpose of the apparatus was not for communication, the small error presented in the apparatus had no problem. The important thing in this application is that the effect of electromagnetic waves with the set frequency that can affect to the termites infestation. Our previous research showed that the set frequency of 300 kHz brings the optimal effect to influence the mortality of termites [15]. The rising time either for set frequency 300 kHz is 1.120 μ s (for V_{pp} 4

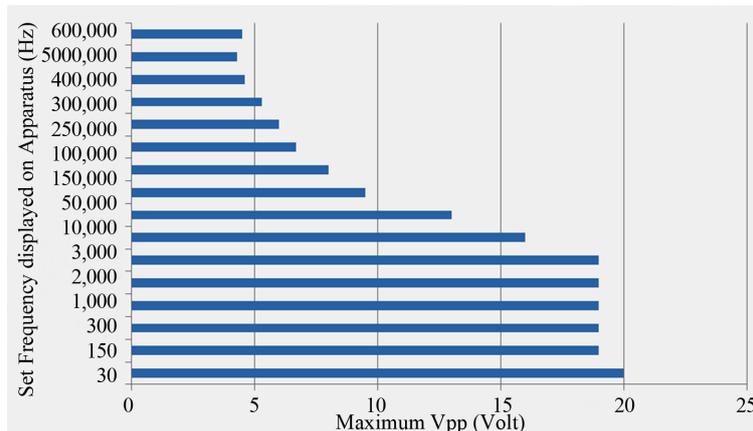


Figure 3. Maximum of Vpp against set frequency.

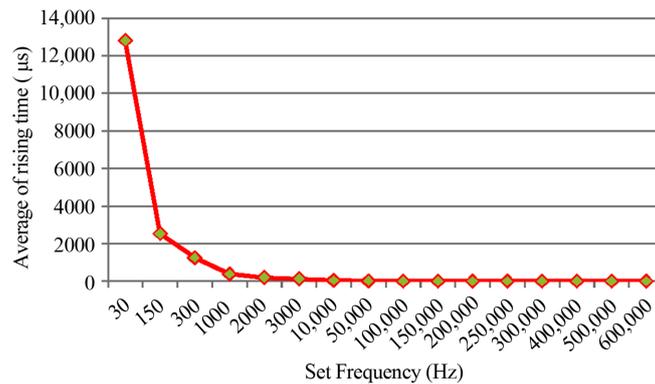


Figure 4. Average of rising time against set frequency.

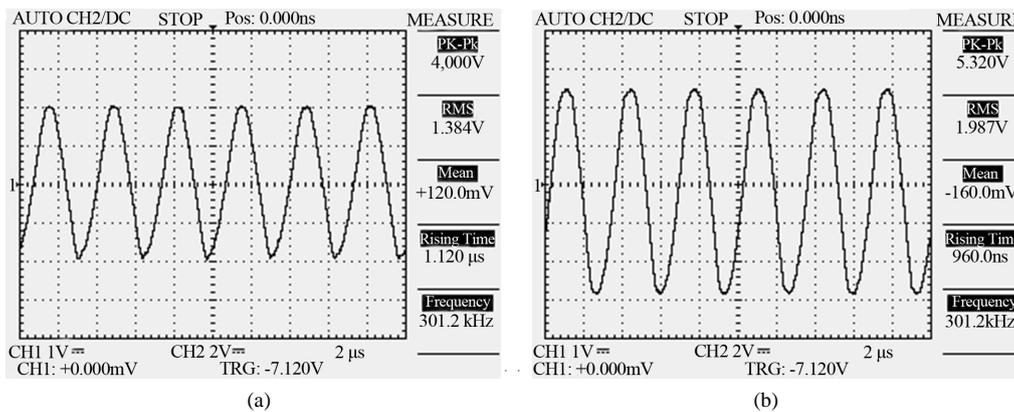


Figure 5. Waveform and electrical parameters of the TCA on frequency 300 kHz. (a) 4 Vpp, (b) 5.3 Vpp.

Volt) and 0.960 µs (for Vpp 5.32 Volt). While for the set frequency 500 kHz, the rising time is about 650 ns. Rising time represents the time needed to reach the set voltage. The faster rising time means the faster set voltage reached.

3.2. Electromagnetic Influence to the Termites

The frequencies of TCA used were 300 KHz; 400 KHz;

500 KHz and 600 KHz respectively. Time exposure of TCA to termites was 60 minutes and 120 minutes. Termites were put in room 4 and after 10 (ten) minute’s exposure, the termites was move to other room of residential building-like test-bed. This can be indicated that termites disturbed by electromagnetic waves. This event occurs for all frequencies of TCA. Similar result was achieved on Kevin *et al.* research [16].

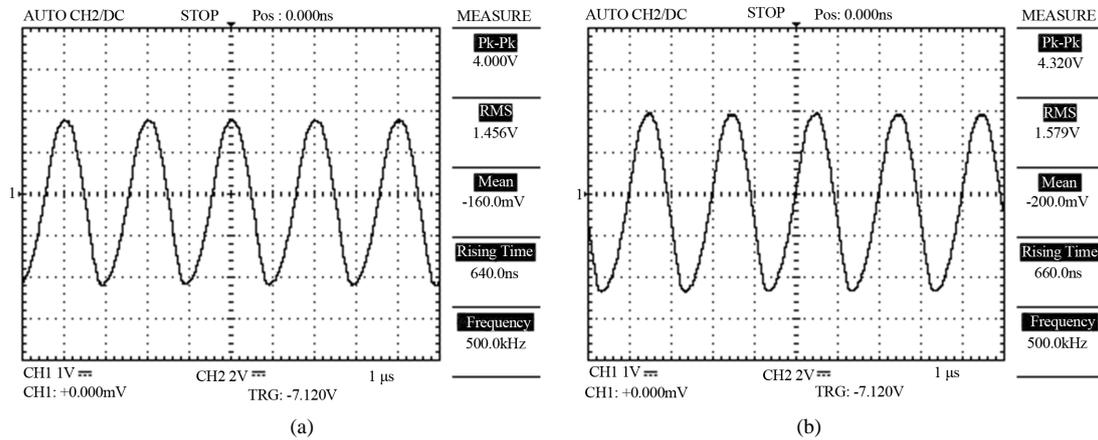


Figure 6. Waveform and electrical parameters of the TCA on frequency 500 kHz. (a) 4 Vpp, (b) 4.3 Vpp.

Table 1. Average error of frequency and voltage.

Set Frequency (Hz)	Average Error = set value – measured value	
	Frequency (Hz)	Vpp (Volt)
30	0.12	0.056
150	0.66	0
300	1.2	0.016
1000	0	0.016
2000	0	0.072
3000	15.6	0.04
10,000	0	0.026
50,000	0	0.32
100,000	0	0.186
150,000	1150	0.04
200,000	800	0.03
250,000	0	0.04
300,000	1200	0.01
400,000	3200	0.04
500,000	0	0.01
600,000	6050	0.01

During exposure of electromagnetic waves, termites were tended to move away from the container. When the frequency electromagnetic waves was 300 kHz the termites moves from room 4 to other room, *i.e.* room 3, room 2 and main hall. After 60 minutes exposure there are some worker of termites loss of stability. When the frequency electromagnetic waves was 400 kHz the termites moves from room 4 to room 3 and main hall. After 60 minutes exposure there are some worker of termites loss of stability and lying. Similar result was achieved

when the frequency of electromagnetic 500 kHz. The termites move to room 3 and main hall and after 60 minutes we found some termites worker lying. When the frequency of electromagnetic waves was 600 kHz the termites look disturbed, they loss of stability, shaking and some termites moves from room 4 to main hall only. They cannot reach the room 3 and other room. This is because the effect of electromagnetic so strong and on the treatment 120 minutes of exposure time, we found some workers of termites death. This could indicate that electromagnetic fields affected the physiology of termites and acted as a repellent to termites. According to Kevin *et al.* [16] termites movement was positive directed by radio waves and electromagnetic waves and they could be used as control apparatus for termites.

The average value of termites mortality was higher on frequency 600 KHz than other frequency and higher on exposure time 120 minutes than 60 minutes respectively as shown in Table 2. According to Kraus [17] electromagnetic waves has an effect to nervous system. He has found that there is a complex field pattern which is spatially related to the anatomical arrangement of the nervous system. The time of exposure of electromagnetic waves had a positive effect to the value of termites mortality. The longest time of exposure of electromagnetic waves caused the highest average value of termites mortality. It can be seen that the effect of electromagnetic related to the frequency and time of exposure. The lower time of exposure determined for the application of apparatus means the the lower effect to the termites mortality. This could be indicated that further application of TCA in residential need more than 120 minutes to move the termites colony away. Electromagnetic waves are combination of electric field and magnetic field which frequencies provide the main influence to materials [18]. Ivanovich [19] stated that storage of agricultural products in the warehouse that were given low-frequency electromagnetic waves have a positive impact.

Table 2. Mortality of termites *C. curvignathus* after irradiation with electromagnetic waves from TCA with different frequency and time of exposure.

Frequency	Time Exposure	
	60 minutes	120 minutes
300 KHz	9.09 ^a	13.64 ^a
400 KHz	11.36 ^a	17.27 ^b
500 KHz	20.45 ^b	26.18 ^c
600 KHz	27.91 ^c	37.73 ^d

^aMeans ($n = 5$) \pm SD. Numbers followed by different letters (a-d) are significantly different at the level of $P < 0.05$ according to Tukey's test.

Agricultural products are of good quality. Thus the frequency has a significant impact on the use of electromagnetic waves.

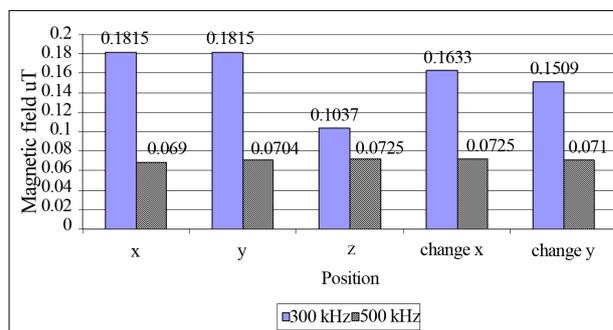
The frequency must be determined to be applied for a special purpose. Furthermore, the effect of frequency to produce electromagnetic waves give more effect to the termites mortality then the safetiness of TCA need to be evaluated. Other research by Nakai *et al.* [12] using microwave energy with two frequencies, 2.45 GHz and 5.8 GHz to control the drywood termites *Incisitermes minor* and the subterranean termites *Coptotermes formosanus* Shiraki. It was reported that the mortality of termites was higher at the higher microwave energy and longest irradiation time. The highest termites mortality value, both on *Coptotermes formosanus* and *Incisitermes minor* termites was obtained when termites were exposed to microwave energy on frequency 5.8 GHz than 2.45 GHz. Furthermore, previous result of the authors related to this paper also achieved the similar result [15].

3.3. Safetiness

The frequency designed for TCA must be checked for their effects on human beings. According to Kato [14] the frequency of electromagnetic waves has a relation with bio-electromagnetic and relatively a new area of science that deals with the interaction of electromagnetic energy with biological systems. The safetiness analysis of the built apparatus was done at Research Institute for Sustainable Humanosphere (RISH), Kyoto University, Japan.

The measurement was carried out respectively on the axis x, y and z (three dimension of field radius) in which the electromagnetic wave propagation data on each axis was done of the difference varies with the distance of 1 cm. Ten replications were done for each position. To measure and evaluated the range of magnetic field we use EMF Hioki 3470-10 (Japan).

Figure 7 shows the average value of magnetic field

**Figure 7.** Magnetic field from TCA with frequencies 300 kHz and 500 kHz.

from electromagnetic waves apparatus for the frequency range at 300 kHz and 500 kHz in terms of x-y-z axis. The measurement was purposed to investigate its impact to the human. The electromagnetic field can also be found on many electronic appliances such as hair dryers (0.1 - 70 μ T), coffee makers (0.4 - 1 μ T), mixers (3 - 60 μ T), washing machines (0.4 - 10 μ T), fax machines (0.4 - 0.9 μ T) and so forth. From the few examples of magnetic field data in some electronic equipment that is used daily in the household, it was proven that the electromagnetic waves apparatus used in the present study was safe to use and did not have an influence on human beings.

The measurement results of magnetic fields for frequency 500 KHz was obtained that on the x axis was 0.0690 μ T, at the axis y was 0.0704 μ T and, 0.0725 μ T on z axis. Meanwhile, if the measurement was done at the middle coil, then the results of measurement for x axis was 0.0725 μ T and for the y-axis was 0.071 μ T. Referring to the data from the National Research Council, USA 1997 [20], it clearly shows that the use of this TCA apparatus at a frequency of 500 KHz has no impact to the biology metabolism of human beings.

4. Conclusion

The present study has elucidated that the TCA electromagnetic-based technology has potential to be applied to control termites infestation by influencing their infestation. A compact apparatus has been built and tested. The optimal frequency for this apparatus to control the termites was 600 kHz. Furthermore, some little errors were still found in some frequencies in terms of frequency and voltage of apparatus compared to the measurement using oscilloscope. However, this error was still in the tolerance since the application was not for communication. In term of time of exposure, it is better to use more than 120 minutes. For safetiness, the apparatus is safe for application around human beings since the magnetic fields produced is still in tolerance. This paper presents an important information for non-destructive and environ-

mental friendly termites control technology in spite of using the insecticides.

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